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Abstract

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Keywords

How people learn, SoTL of bioengineering, Pedagogical practices

Operationalization of Innovative and Traditional Pedagogical Practices within Undergraduate Bioengineering Courses

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Abstract

This study operationalizes pedagogical practices using classroom observation data collected in twenty-eight bioengineering courses at a southeastern research university over five semesters. Using an index that distinguishes pedagogy reflecting principles of the “How People Learn” framework and pedagogy representing traditional, lecture-based instruction, the author presents five “How People Learn” instructional practices (i.e., guidance by the instructor, comments, praise, monitoring, and question and response) and four statistically significant subcategories representing traditional instructional practices (i.e., instruction by media, lecture, praise, and no response) that were most likely to occur within observed How People Learn-oriented classes and traditional, lecture-based classes, respectively. Included are details about classroom activities that occurred to make up the code strings representing each of these statistically significant subcategories within both types of courses. The operationalization of the code strings confirms the alignment of the subcategories with pedagogical practices that are most likely to occur within innovative and traditional courses.

Introduction

Although effective pedagogical practices have been explored independently of context, several researchers have noted the impact of effective pedagogical practices within engineering. Engineering studies are needed since engineering is a “hard/applied” field of study that differs from other studies given its emphasis on inquiry, its inclusion of the environment, and its focus on products and on the processes that are needed to produce such products (Biglan, 1973; Lodahl & Gordon, 1972; Neumann, Perry & Becher, 2002). More than in lecture-based classes, engineering classes with emphases on in-class student collaboration and on faculty and student interactions have been reported to increase student outcomes such as critical thinking skills, achievement, persistence, and attitudes (Cabrera, Colbeck, & Terenzini, 2001; Cooper & Robinson, 1998; Cudd & Wasser, 1999; Springer, Stanne, & Donovan, 1998).

To observe engineering classroom environments, members of the assessment and evaluation team within the Vanderbilt University, Northwestern University, the University of Texas at Austin, and the Harvard/Massachusetts Institute of Technology Division of Health Science and Technology (VaNTH) Engineering Research Center (ERC) for Bioengineering Educational Technologies (VaNTH, 2007) created a four-part direct observation system called the VaNTH Observation System (VOS) (Harris & Cox, 2003). The primary purpose of the VOS was to examine the extent to which the four lenses of the “How People Learn” (HPL) framework, knowledge-, learner-, assessment-, and community centeredness, were present within observed bioengineering classrooms within the ERC (Harris & Cox, 2003). A *knowledge-centered* environment promotes learning with understanding via an organization

of academic knowledge around core concepts of the subject domain area and an understanding of the when and how to apply these concepts (Bransford, Brown, & Cocking, 1999). Within a *learner-centered* environment, an instructor takes into account the knowledge, skills, beliefs, preconceptions, misconceptions, and learning styles of the students and acknowledges challenges that some students may have within a classroom. *Assessment-centered* environments allow students and faculty to make their thinking and learning visible and to revise this thinking through the use of feedback techniques. A *community-centered* learning environment encourages students to share norms that value learning and high standards. This community includes the classroom, the school, and the connections between the school and the larger community, including the home.

The author developed an index called the HPL Index to parse data from the one portion of the VOS into code strings representing either HPL-oriented instruction or code strings representing traditional, lecture-based instruction. This resulted in the creation of both HPL-oriented instructional subcategories and traditional, or lecture based instructional categories. In a criterion contrast study to distinguish pedagogy in seventeen HPL-oriented courses and eleven traditional or lecture-based courses, the author found that the HPL-oriented courses, more than traditional courses, demonstrated subcategories representing innovation instructional pedagogical practices most aligned with the HPL framework. On the other hand, traditional courses, more than HPL-oriented courses, were more likely to demonstrate subcategories representing traditional, nonHPL-oriented instructional practices (Cox & Cordray, 2008). Missing within this previous study, however, were details about the actual classroom activities that occurred to make up the frequencies represented by each of these statistically significant subcategories within traditional and HPL-oriented courses. For this reason, the purpose of this paper is to operationalize the pedagogical practices associated with these occurrences. More specifically, the research questions for this study are (1) "What 'How People Learn'-oriented pedagogical practices are most prevalent across all observed engineering classrooms using the HPL Index?" and (2) "What traditional pedagogical practices are most prevalent across observed engineering classrooms using the HPL Index?"

Methods

Participants

The analyses using the HPL Index are based on 182 classroom observations in twenty-eight (28) bioengineering courses at a southeastern research university. Such courses included Freshman Seminar, Systems Physiology, Biomechanics, Biotechnology, Senior Design, and Bioethics. Data were collected by five trained VOS observers during five semesters between spring 2002 and spring 2004. Classes were visited approximately eight times over the course of the semester, and observers collected data for the entire class period (i.e., 50 minutes, 1 ½ hours, or two hours). Courses ranged from sophomore- to senior-level, and were designated as traditional or HPL by educational researchers in VaNTH prior to the semester that the class was observed. Seventeen of these courses primarily implemented HPL-oriented pedagogical practices, and eleven primarily used traditional, or lecture-based engineering practices. Although faculty teaching the HPL-oriented courses received no formal pedagogical training within their classes prior to their implementation of HPL materials, they consistently assisted in the design and implementation of curricula incorporating elements of the HPL framework within their courses. Traditional faculty, on the other hand, did not incorporate formally HPL-oriented materials in their courses and, therefore taught their courses in their usual manner.

Measures

Data were collected using the HPL Index, which was confirmed to be sensitive enough to capture HPL-related differences in courses known to employ HPL-based or traditional pedagogy (Cox & Cordray, 2008). The Index analyzes data collected within the first part of the VOS, the Classroom Interaction Observation (CIO), which explicitly records faculty-student interactions, in real-time, within classes, using elements that integrate the HPL framework principles (Harris & Cox, 2003) (Figure 1). Each CIO coding session is approximately three minutes in length and is followed by three components of the VOS. As such, VOS observers record approximately thirty to forty-five CIO code strings at the speed of speech during each three minute session, resulting in hundreds of CIO code strings being collected per observed class session.

WHO	TO WHOM	WHAT	HOW	MEDIA
Professor	Professor	1 factual question	Knowledge-centered	Board
Everyone	Everyone	2 higher order question		Overhead
First student	First student	3 response	Learner-centered	Computer
Same student	Same student	4 instruction	Assessment-centered	Simulation
Small group	Small group	5 social comment	Community-centered	Demonstration
Large group	Large group	6 activity-related comment		Video
Group	Group	7 acknowledge/ praise	Class	Response system
Media	Media	8 guide	Organization	None
Visitor	Visitor	9 correction		
		0 no response		
		A active monitoring		
		P passive Monitoring		

Figure 1. VaNTH Observation System Classroom Interaction Observation (CIO) codes (Harris & Cox, 2003).

The HPL Index was created for a couple of reasons. First, unlike previous systems that only analyzed CIO data using the *how* category, the HPL Index groups data into code strings that incorporate the *who* - *to whom* - *what* - *how* - *media* categories. This allows for a single index from which to compare pedagogical styles in traditional and nontraditional engineering classrooms and represents the interplay of HPL lenses and other HPL-oriented behaviors such as higher order questioning, guidance by an instructor, and group work. Second, each of the code strings analyzed using the Index represent traditional instruction, HPL-oriented instruction, or organization and sum to 100% of observed classroom time. Only codes representing traditional or HPL-oriented instruction, however, are of interest within this study.

Suppose that a professor asks students who are working in groups a higher order question about a diagram displayed on the overhead. Within the HPL Index, the corresponding CIO code string would be "P-g-2-K/L/A-O" such that "P" represents the professor who is initiating the question (*who*), "g" represents the small group of students to whom the professor is asking the question (*to whom*), and "2" represents the higher order question that was asked (*what*). HPL dimensions represented are knowledge-centered (K), learner-centered (L), and assessment-centered (A) since the groups of students are engaging in content deeply and the groups are being asked a question about the extent to which they understand course material (*how*). The use of the overhead is represented by "O" (*media*).

Since multiple HPL dimensions are being used, this code string would be categorized within the HPL Index as a HPL-oriented instructional code string within an HPL subcategory called “higher order questioning by the instructor”.

Previous Work

To date, the HPL Index has been used to categorize over 36,000 code strings across the 28 observed courses. HPL-oriented subcategories were categorized based upon their integration of HPL-oriented principles, and traditional subcategories were categorized based upon their absence of multiple HPL-oriented dimensions. The sum of all HPL-oriented instructional subcategories and the sum of all Traditional instructional subcategories were found to be statistically significant for both HPL-oriented and traditional courses, thereby supporting running additional independent t-tests on each of the 18 subcategories. Using independent sample t-tests and a Bonferroni correction to calculate an individual $p < 0.003$ for each subcategory, five HPL subcategory items and four traditional subcategory items were found to be statistically significant (Table 1). The criterion contrast of the Index was confirmed further, since, compared to traditional, lecture-based classes, HPL-designated classes reported higher occurrences for all of the statistically significant HPL subcategories, and compared to HPL-designated classes, lecture-based classes reported higher occurrences for three of the four statistically significant traditional subcategory items. Definitions of each of these items along with their frequencies of occurrence within both HPL-oriented and traditional, lecture based courses are found in Table 1.

Category	Statistically Significant Subcategory & Definition	HPL-Oriented Courses (N=17)	Traditional Courses (N=11)	p value
HPL	<i>Guidance by the Instructor.</i> An instructor leads students to correct answers that they are trying to solve in class.	232 (0.99%)	88 (0.69%)	0.002***
	<i>Comment(s).</i> An instructor or students make in-class comments about academic content using multiple HPL dimensions.	690 (2.94%)	222 (1.74%)	0.000***
	<i>Praise.</i> An instructor praises students after they respond to an HPL-oriented question or HPL-oriented comment.	249 (1.06%)	74 (0.58%)	0.000***
	<i>Monitoring.</i> An instructor observes students or walks among them as they work on in-class activities that represent multiple HPL dimensions.	544 (2.32%)	88 (0.69%)	0.000***
	<i>Question and Response.</i> Lower-level (yes or no) questions and responses to questions that represent multiple HPL dimensions.	836 (3.56%)	210 (1.65%)	0.000***
Traditional	<i>Instruction by Media.</i> This represents media-led classroom instruction (e.g., video) that represents only the knowledge-centered dimension.	18 (<0.1%)	28 (0.22%)	0.002***
	<i>Lecture.</i> This occurs when an instructor lectures using only the knowledge-centered dimension or the knowledge-centered and assessment-centered dimensions.	11354 (48.41%)	6729 (52.85%)	0.000***
	<i>Praise.</i> This occurs when an instructor praises students after they respond to a lower-level "yes" or "no" question or to a question that does not represent the integration of multiple HPL dimensions.	340 (1.45%)	131 (1.03%)	0.000***
	<i>No response.</i> This relates to students not responding to a professor's question that uses only the knowledge-centered dimension or knowledge-centered and assessment-centered dimensions.	82 (0.35%)	79 (0.62%)	0.001***

Table 1. Statistically significant HPL-oriented instruction and traditional instruction subcategories along with general definitions of the subcategories.

Family p < 0.05

Corrected individual p < 0.003

Procedures

In an effort to understand more about the classroom activities that are associated with the frequencies in Table 1 and the corresponding codes strings in Table 2, the objective of the current study is to operationalize both HPL-oriented and traditional pedagogical practices

associated with the subcategories within this table. This will occur by identifying the Classroom Interaction Observation code strings that are represented within each of the statistically significant subcategories and by translating them into language representing instructional practices that might occur within a classroom setting. In this way, both researchers and practitioners can begin to have conversations about practices that are and are not occurring within their courses. Only code strings with frequencies greater than 0.1% for each of the subcategories will be included in the representations for each subcategory.

How People Learn-oriented categories

The five HPL subcategories in which HPL-oriented courses differed from traditional, lecture-based courses included the following: (1) guidance by the instructor, (2) question and response, (3) monitoring, (4) praise, and (5) comments. The percentage of observed instances of occurrence of code strings (across all twenty-eight classes) for the most frequently occurring activities within each category are listed in Table 3 followed by a discussion of these subcategories and their operationalization.

Index Subcategory	CIO Who Category	CIO To Whom Category	CIO What Category	CIO How Category	CIO Media Category	Percent of Observed Instances
HPL Guidance by the professor	P or V	E	8	Any code excluding O	Any code excluding R	215 (0.59%)
	P or V	S	8	Any code excluding O	Any code excluding R	85 (0.24%)
HPL Question and Response	P or V	g	1 or 3	Any code excluding O	Any code excluding R	59 (0.16%)
	P or V	E	1 or 3	KAL, KAC, or KLAC	Any code excluding R	150 (0.42%)
	P or V	S	1 or 3	KAL, KAC, or KLAC	Any code excluding R	110 (0.31%)
	E	P or V	1 or 3	KAL, KAC, or KLAC	Any code excluding R	52 (0.14%)
	g or G	P	1 or 3	Any code excluding O	Any code excluding R	325 (0.90%)
	F	P or V	1 or 3	KAL, KAC, or KLAC	Any code excluding R	253 (0.70%)
	S	P or V	1 or 3	KAL, KAC, or KLAC	Any code excluding R	75 (0.21%)
HPL Monitoring	P or V	g or G	A or P	Any code excluding O	Any code excluding R	410 (1.14%)
	P or V	E or F	A or P	KAL, KAC, KLAC	Any code excluding R	222 (0.62%)
HPL Praise	P or V	g	7	Any code excluding O	Any code excluding R	122 (0.34%)
	P or V	S	7	KAL, KAC, KLAC	Any code excluding R	153 (0.43%)
HPL Comments	P	g	6	Any code excluding O	Any code excluding R	114 (0.32%)
	g	P	6	Any code excluding O	Any code excluding R	60 (0.17%)
	S	E	6	Any code excluding O	Any code excluding R	174 (0.48%)
	P or V	E	6	KAL, KAC, KLAC	Any code excluding R	48 (0.13%)
	P or V	S	6	KAL, KAC, KLAC	Any code excluding R	47 (0.13%)
	P or V	E	6	KL, KC, or KLC	Any code excluding R	382 (1.05%)

Table 2. Classroom Interaction Observation code strings represented >0.1% of observed instruction for statistically significant HPL subcategories.

Within the sample of bioengineering courses, instructors within HPL courses were more likely to *guide* students to answers instead of just correcting them when they responded incorrectly to an answer. More specifically, instructors guided either an entire class to a correct answer or guided a single student who had begun previously to talk about a concept

within the course. To guide the entire class, the instructor often gave students prompts after no one responded to a question. When guiding a single student, the instructor helped to clarify or to refine a student's thinking about an academic concept. *HPL questions and responses* occurred when students or instructors asked lower-level (yes or no) questions that integrated more than one of the four HPL lenses or when students or instructors responded to any question (i.e., higher-order or lower-level) incorporating these lenses. Other instances of question and response included an instructor or members of a group asking or responding to academic content during small or large group student activities. *Monitoring* involved the instructor engaging with students during group work or the instructor watching students as they worked in groups or individually during class. *HPL praise* most likely occurred when the instructor commended a small group as they worked in class or when a single student who had begun previously to talk about a concept correctly described a concept that represented multiple HPL lenses. Finally, *HPL comments* most often involved an instructor, a small group, or a single student who had begun previously to talk about a concept that was not lecture but somehow supplemented the ideas presented within the lecture. In addition, instructors were most likely to talk about a tangential comment to the entire class or to a student who had begun previously to talk about a concept that was a supplement to the lecture content.

Traditional Instructional Categories

The four statistically significant traditional subcategories included the following: (1) instruction by media, (2) traditional lecture, (3) traditional praise, and (4) no response in a traditional environment. The occurrence of these traditional subcategories was more prevalent in traditional, lecture-based classes for all of the subcategories except for the subcategory of traditional praise. Each of these subcategories and their operationalization are discussed below, and the percentage of observed instances of occurrence of code strings for the most frequently occurring activities within each category are listed in Table 3.

Index Subcategory	CIO Who Category	CIO To Whom Category	CIO What Category	CIO How Category	CIO Media Category	Percent of Observed Instances
Instruction by Media (Traditional)	M	E	4 or 6	Any code excluding O	Any code excluding R	46 (0.13%)
Traditional Lecture	P or V	E	4	K or KA	Any code excluding R	18033 (49.65%)
Traditional Praise	P or V	S	7	K or KA	Any code excluding R	433 (1.20%)
Traditional, No Response	E	P or V	0	KA	Any code excluding R	148 (0.41%)

Table 3. Classroom Interaction Observation code strings representing >0.1% of observed instruction for statistically significant traditional subcategories.

Within the sample of bioengineering courses, instructors within traditional courses were more likely to use *instruction by media*. In this way, instructors used any form of media to lecture to students about course content or to provide supplemental information to students about academic content. *Traditional lecture* was the more commonly used instructional practice across the traditional and HPL-oriented courses and was most prevalent when the instructor taught academic content to the entire class. *Traditional praise*, which occurred more often in HPL-oriented classes, occurred when an instructor commended a student after

he/she provided a correct response to a question asked by the instructor. Finally, *no response* in a traditional environment was prevalent when all students did not respond to the instructor's questions about some content that did not represent multiple HPL dimensions.

Discussion

Within this paper, five HPL-oriented subcategories and four traditional subcategories were most likely to occur within observed bioengineering courses. Occurrences within both types of courses align with findings observed within innovative courses and in traditional, lecture-based courses. For example, the HPL-oriented courses reported effective pedagogy such that instructors probed students' understanding of course content by providing reflexive tosses (Zee & Minstrell, 1997), by engaging students in higher order questioning and active learning via the use of group activities (Springer, et al., 1998), and by involving students in inductive teaching and learning approaches and conversations that allow them to think about course concepts beyond the traditional academic context (Prince & Felder, 2006). Aligned with Boyer's (1990) definition of the scholarship of teaching, these activities ultimately can build bridges between teacher's understanding and students' learning and allow faculty to be learners as well. On the other hand, traditional activities within observed courses paralleled activities that are most likely to occur within lecture-based classroom environments. Among these occurrences included uses of technology such that students do not engage interactively with the technology and delivery of lecture such that the instructor statically stands before students and presents course information without much interaction with the students (Felder, Woods, Stice, & Rugarcia, 2000).

Despite the alignment of the research findings to the findings within previous literature, limitations still exist. First, this paper presents the frequencies of occurrences within the classrooms, not the sequence of these activities. In other words, although data are reported about the kinds of occurrences that occurred most often within undergraduate bioengineering courses, no information was presented about the activities that preceded or followed these occurrences. Such information could be helpful in developing greater understanding about *what* should be taught within classrooms and *when* it should be taught. Second, data were collected within one discipline (i.e., bioengineering) at one university. To understand if the findings are generalizable, additional classroom observations within other disciplines and at other universities need to be conducted. Finally, since over 100 possible code strings combinations exist and over 30,000 code strings were collected, subcategory frequencies, although statistically significant in sum, were relatively small when broken down into smaller categories. Because of this, the primary focus of the paper was on the operationalization of these code strings, not the magnitude of their occurrence within the HPL Index.

The findings are important for several reasons. It provides insight into the pedagogical practices that occur within postsecondary engineering. Although there is literature that explores pedagogical practices within engineering (Felder & Silverman, 1988), additional information about these practices are needed so that pedagogical practices can be linked eventually to student outcomes (e.g., achievement and retention) within observed courses. Also, findings reported within the HPL Index raise additional questions about the appropriate amount of innovative instruction that is needed within courses. As seen within Table 3, although courses are designed to be innovative, the dominant pedagogical practice is still lecture. By having a tool such as the Index and by operationalizing the code strings, researchers and practitioners can begin to have discussions about the appropriate amount

and the types of innovative pedagogy needed to achieve outcomes within courses across a variety of contexts. Because the criterion contrast of the HPL Index has been confirmed, additional direct observation instruments that explore additional constructs based upon pedagogical theories and practices of interest might be developed.

Conclusions

This paper details the pedagogical practices that were present across twenty-eight (seventeen How People Learn-oriented and eleven traditional, lecture-based) bioengineering courses. Although the majority of the occurrences within both types of courses were comprised of lecture, other instances of innovative pedagogy occurred predominately within courses that were purposefully designed to represent principles of the How People Learn framework. The operationalization of both HPL-oriented and traditional subcategories using the HPL Index facilitates conversations about ways to connect pedagogical theory to practice, provides a snapshot of pedagogy within postsecondary engineering education, and lays a foundation for future studies that explore theory-based pedagogical practices in multiple environments.

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